

## MODIS Semi-Annual Report, June 2001

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This reports covers the **aerosol ocean** and **aerosol land** algorithm, and our involvement in the **NIR water vapor**, **cirrus** and the **fire** algorithms. It is the first to cover actual use of the MODIS data.

### Main topics addressed in this period:

#### AEROSOL OVER LAND AND OCEAN

1. Validation of MODIS aerosol optical depth over land - comparison with non-AERONET aerosol measurements in Zambia (*Chu, Kaufman, Levy*)
2. Retrieval/analysis of China dust outbreak events during ACE-Asia 2001 (*Chu, Kaufman, Li*)
3. Derivation of dust single scattering albedos during African dust outbreaks (*Kaufman, Li, Chu*)
4. Global and regional monthly variation of aerosol optical depth observed by MODIS (*Chu, Kaufman, Li*)
5. Regional aerosol radiative forcing calculation over ocean (*Kaufman, Remer, Chu*)
6. Regional analysis of MODIS aerosol retrievals for various aerosol events (*Kaufman, Li, Chu*)

#### ALGORITHM ENHANCEMENT & DEVELOPMENT

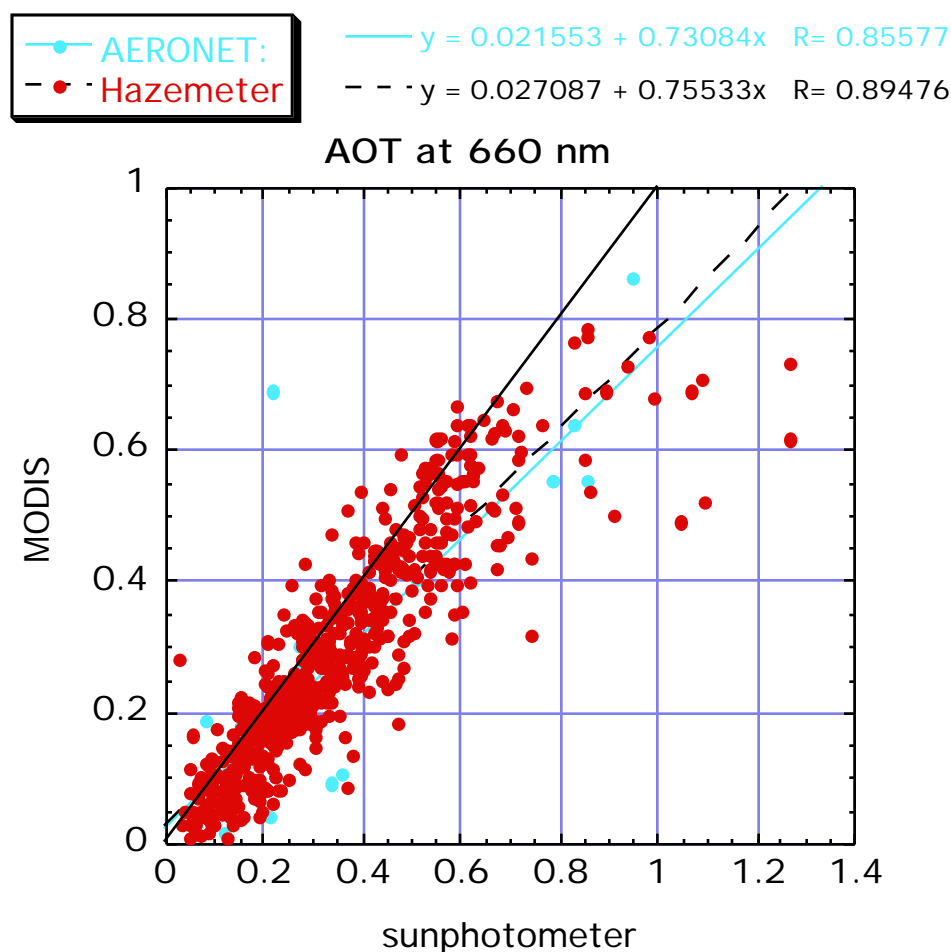
7. Delivery of MODIS PGE04 version 2.8.0 & 2.8.2 algorithm for consistent-year MODIS data processing (*Chu, Mattoo, Remer, Kaufman, Tanre*)

#### OTHER TOPICS

8. Data analysis of PRIDE MODIS/AERONET measurements (*Remer, Levy, Kleidman*)
9. Enhancement of the automated daily process of the generation of the MAPSS database from MODIS and AERONET aerosol and water vapor products (*Ichoku, Kaufman, Remer, Chu*)
10. Calibration and analysis of Microtops sunphotometer measurements (*Ichoku, Kaufman*)
11. Coding of transformation of MODIS fire product into climate modeling grid (*Ichoku*)
12. Study of sub-pixel snow/ice detection using 0.66 and 2.1  $\mu\text{m}$  channels (*Kleidman, Kaufman*)
13. Analysis of Japanese assimilation model results (*Li, Kaufman*)
14. Development of aerosol transport model (*Dubovik, Lapyonok, Kaufman,*)
15. Participation in ACE-Asia field experiments (*Chu*)
16. Integration of MODIS data with PICASSO and MISR (*Kaufman, Shana, Kleidman*)
17. Paper acceptance/submission/preparation (*Kaufman, Remer, Chu, Ichoku, Kleidman*)
18. Meeting and workshop (*Kaufman, Remer, Chu, Mattoo, Li, Kleidman, levy, Ichoku*)

# 1. Validation of MODIS aerosol optical depth over land - comparison with non-AERONET aerosol measurements in Zambia

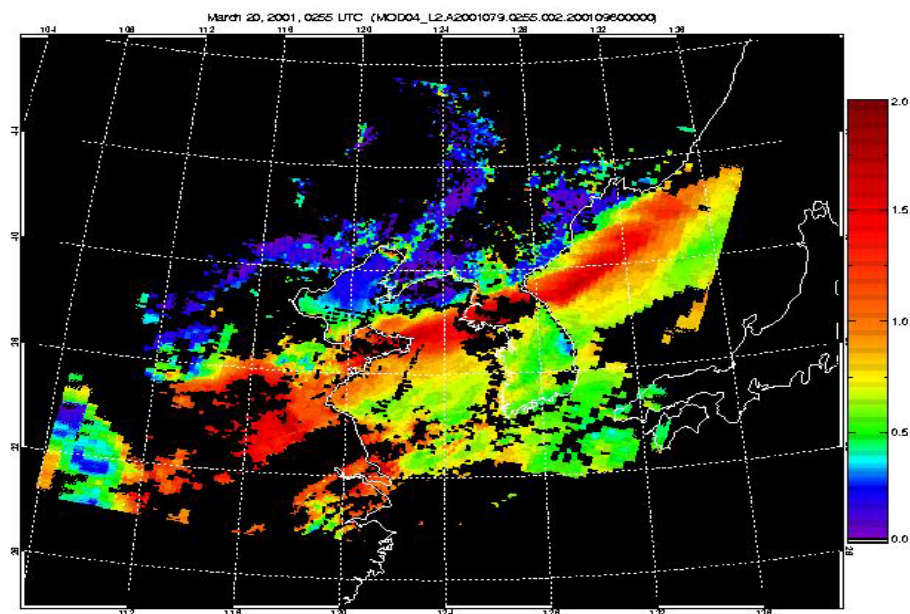
The comparison of MODIS-derived optical depth and Haze-meter Network measurements during the SAFARI 2000 field experiment in Zambia serves as an additional database for the validation of MODIS aerosol product. A total of more than 900 measurements were acquired during August - October 2000 from more than 20 locations in Zambia. Shown below is the comparison of MODIS-derived aerosol optical depth vs. Haze-meter (red) and AERONET (blue) observations at 0.66  $\mu\text{m}$ .



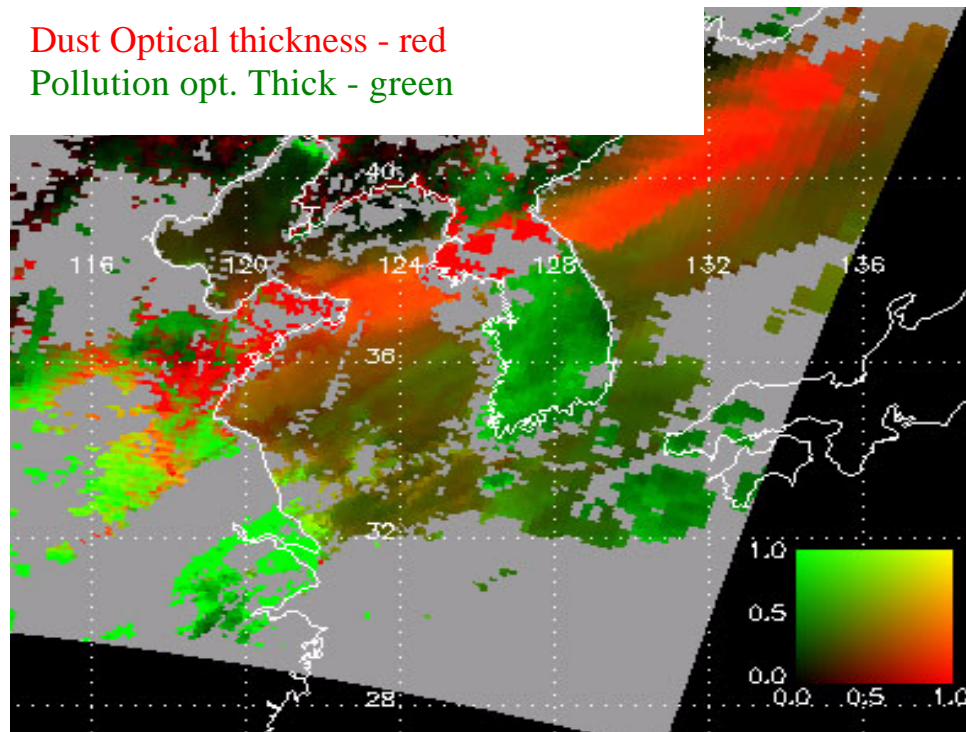
It is consistent with the conclusion obtained from the comparison between MODIS and AEORNET observations that the MODIS-derived aerosol optical depths are slightly lower than those obtained from AERONET Sun photometers. In the other words, lowering the single scattering albedo in MODIS retrieval should result in better fit of the linear regression because of more soot particles are emitted from African biomass burning compared to South American biomass burning. The MODIS algorithm is based on the South America analysis.

## **2. Retrieval/analysis of China dust outbreak events during ACE-Asia 2001**

The ACE-Asia 2001 is the first field experiment of the comprehensive study of China dust characteristics. The drought caused by global climate change as well as the man-made influence on the local ecosystem (e.g., the land use and land development) have both contributed to the occurrence of dust events. In the year 2001, a total of 18 dust storm (3 major, 10 medium, and 5 light) dust outbreaks were recorded in northern China in 2001. On average, dusty weather occurred very other day since the beginning of the spring season. The total of dusty days has exceeded 40 days. The occurrence of dusty days was much higher in April than in March. The frequency of dust outbreaks has increased significantly since 1998, which reversed from what happened in early 1990s with decreasing trend since 1950-1960. The two major sources of dust outbreaks are Xinjiang Province (western China) and Inner Mongolia (northern China). Especially in Xinjiang Province, desertification has increased by 400 km<sup>2</sup> a year. Overall, the desertification has reached 27% of the total land area of China and the economical impact is approximately 54 billion RMB annually. Shown below is an example of MODIS-derived aerosol optical depth of a dust front (red) passing on top of existing pollution (green to yellow) through Korea Peninsula on March 20, 2001. The scale on the right is for optical thickness of 0.0 to 2.0



The corresponding distribution of fine/coarse mode aerosols (fine mode: air pollution; coarse mode: dust) derived by MODIS aerosol algorithm reveals reasonable spatial distribution of dust and air pollution aerosols as well as the mixture of the two.

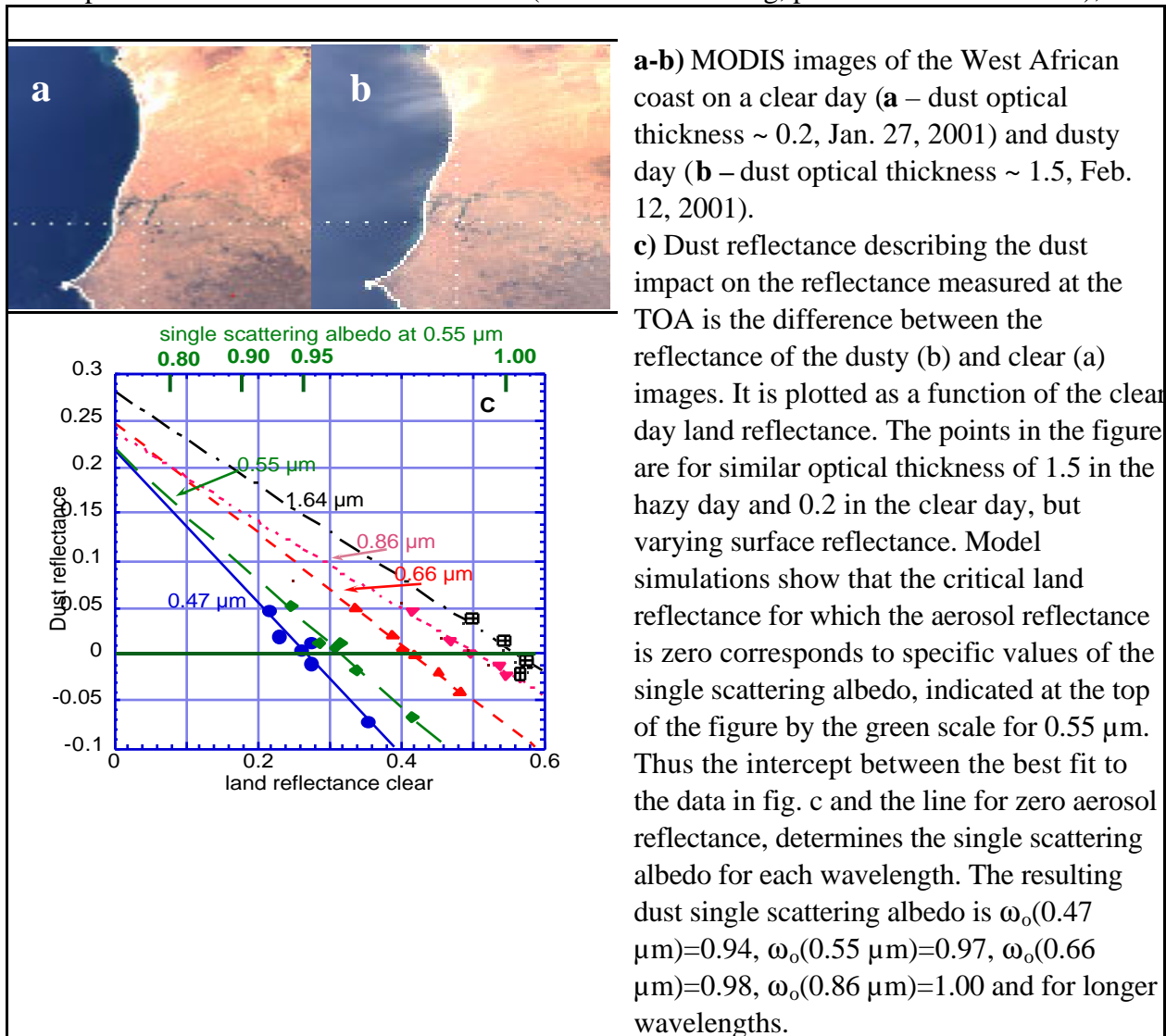


### **3. Derivation of dust single scattering albedos during African dust outbreak events - The difficulties in assessing dust absorption**

The difference between aerosol radiative forcing at the surface and at the top of the atmosphere (TOA) is due to absorption of sunlight. Aerosol absorption is described by the single scattering albedo,  $\omega_0$ , ratio of scattering to scattering and absorption. For smoke and regional pollution a good estimate of the aerosol single scattering albedo was obtained from simultaneous in situ and radiative measurements. For dust a consensus regarding its single scattering albedo is harder to reach.

The dust single scattering albedo used in a recent model is based on interpretation of laboratory measurements done two decades ago.  $\omega_0$  increases from 0.75 in the blue part of the spectrum, to 0.85 in the red, approaching 1.0 (no absorption) for longer wavelengths. Though this general spectral trend is agreed on, the problems in measuring dust absorption and modeling it are too large even to determine if dust heats or cools the Earth system, and whether the inferred response of atmospheric temperature to the dust heating of 0.2 K/day are due to absorption of sunlight or of thermal radiation emitted from the Earth. Significantly lower dust absorption ( $\omega_0 \sim 0.95$  for the entire solar spectrum) was inferred from radiation measurements. Radiative techniques have the advantage of measuring the aerosol in its natural environment (no sampling or heating). This contradiction and scarcity of measurements encouraged the development of new radiative techniques to measure the dust single scattering albedo from ground based (AERONET) and satellite spectral radiometers. Here the satellite technique is demonstrated for MODIS observations

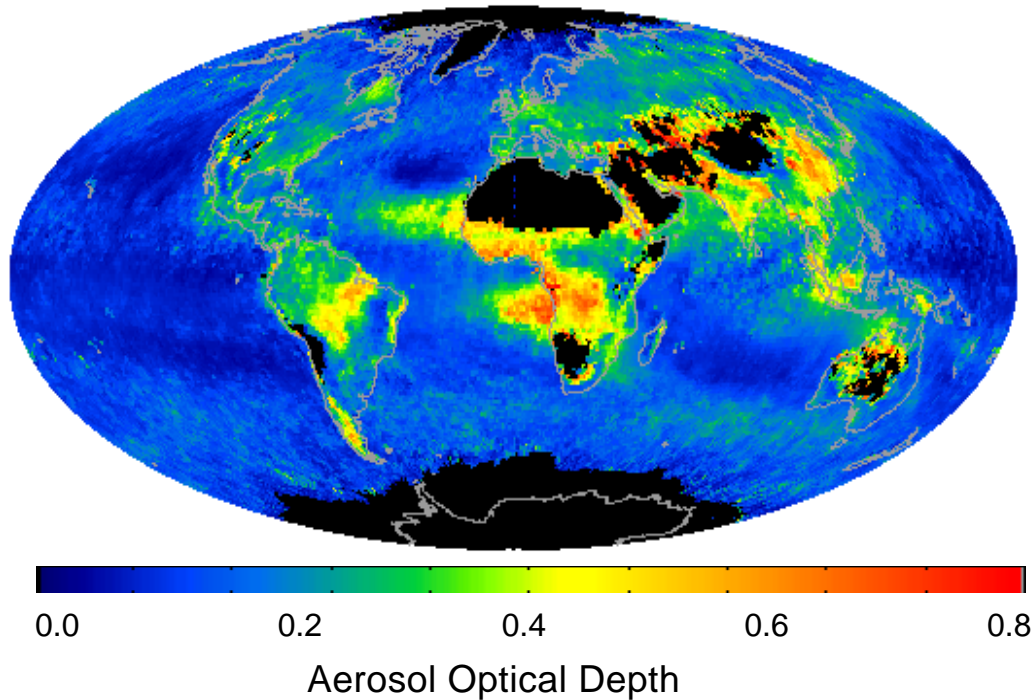
of dust over the West African coast. The difference in bright land reflectance between a clear day (fig a) and a dusty day (fig. b) measures the balance between dust scattering and absorption, determined by  $\omega_o$ . The slightly brighter land image in the dusty day indicates little dust absorption, with  $\omega_o = 0.94$  in the blue ( $0.47 \mu\text{m}$ ), to  $0.98$  in the red ( $0.66 \mu\text{m}$ ) and  $1.00$  for wavelengths longer than at  $0.86 \mu\text{m}$  (fig c), in agreement with the AERONET measurements. Therefore the dust shortwave radiative forcing at TOA is negative, in contrast to previous calculations. Preliminary measurements describing dust outbreaks from Asia and Africa indicate similarly low dust absorption from new in situ measurements (Huebert and Maring, personal communication),



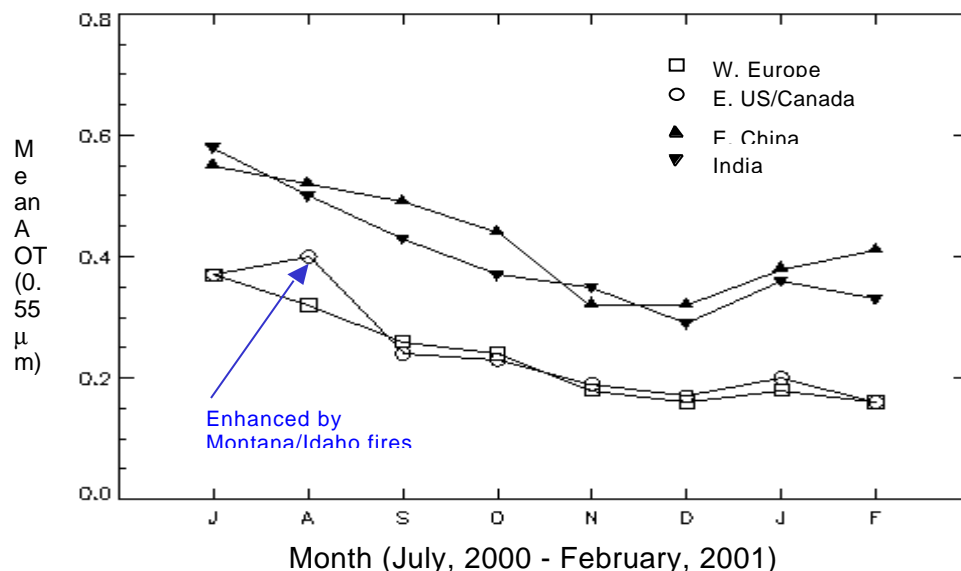
We plan to apply this technique to a wide array of MODIS data. Probably starting from a combination of MODIS and aeronet measurements. However extension to the ocean require the use of glint. We are studying the use of MODIS glint data for aerosol optical thickness and may be absorption measurements.

#### 4. Global and regional variation/distribution of aerosol optical depth observed by MODIS

The MODIS level-3 daily global data were used to derive the global and regional variation/distribution of aerosol optical depths. Shown below is an image of aerosol optical depths derived in September 2001 as an example.

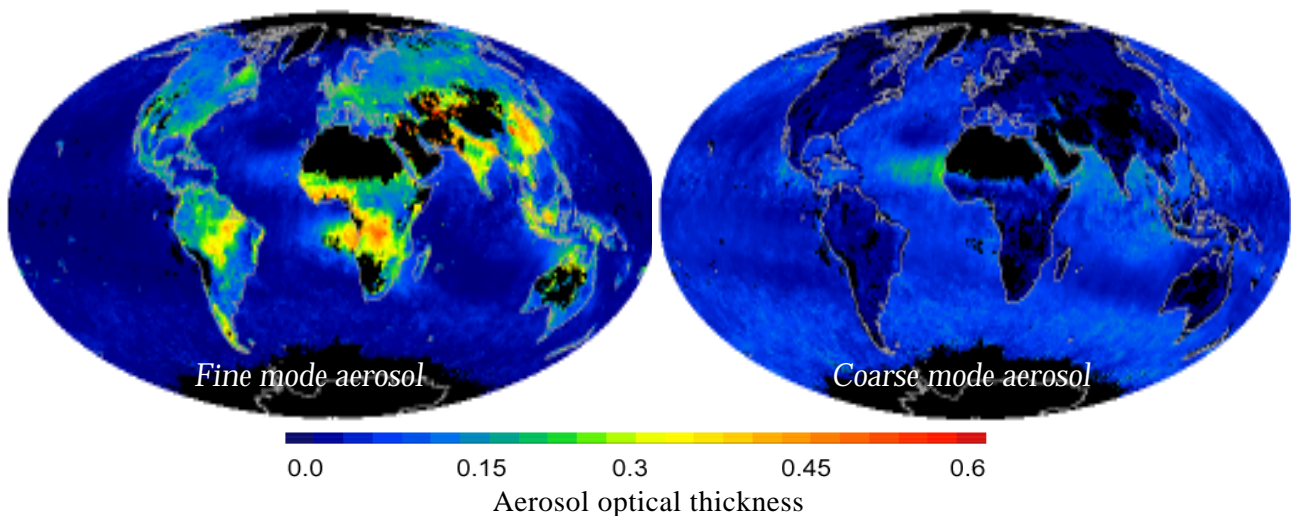


The dry-season biomass burning in African and in South America are most visible with mean optical depths  $\sim 0.5$ - $0.7$  compared to air pollution in Europe and North America (mean values  $\sim 0.2$ - $0.3$ ). High aerosol optical depths are also seen in China and India with means about  $0.4$ - $0.5$ . The monthly means of aerosol optical depth (at  $0.55 \mu\text{m}$ ) in four regions (E. US/Canada, W. Europe, China, and India) between July 2000 and February 2001 show two groups with aerosol optical depth of E. China & India nearly double as compared to that in E. US/Canada & W. Europe.



## **5. Regional aerosol radiative forcing calculation over ocean**

We combined aerosol climatology obtained from years of AERONET data (Dubovik et al 2001) with analysis of MODIS data of the fine and coarse aerosol separately to derive the radiative forcing over the main regions of aerosol using the code of Chou et al. Table 1 shows a summary of the AERONET measurements and the MODIS analysis. Large radiative forcings at the top and bottom of the atmosphere are shown and are expected to make large differences in the atmospheric dynamics and hydrological cycle (Kiehl private communications).



Average global analysis of the fine (left) and coarse (right) aerosol optical thickness at 0.55 μm for September, 2000. The data are from the MODIS instrument launched in Dec 1999 on the NASA Terra satellite. The optical thickness presented by the color scale, is a measure of the aerosol column concentration. Black regions have surface properties inappropriate for MODIS aerosol retrievals. The separation between fine and coarse particles over land and ocean serves to observe the human impact, since heavy smoke and pollution is in the fine mode (left figure), while mainly natural aerosol, dust and sea salt, is in the coarse mode (right figure).

**Table 1: (a) Climatology of aerosol properties derived from systematic multi-year measurements by the Aerosol Robotic Network – AERONET. (b) Analysis of MODIS-Terra satellite oceanic data for Sept. 2000. Both represent measurements of the ambient aerosol in the atmospheric column. In (a) four aerosol types are shown with a representative size distribution: 1) Pollution from Eastern US (Greenbelt, Maryland)& Europe (Venice and Paris), South East Asia (Maldives-INDOEX) and Central America (Mexico City). 2) Biomass burning from Africa and South America. 3) Dust over the Atlantic Ocean (Cape Verde) and 4) Maritime aerosol over the Pacific Ocean (Lanai). In (a) all values except of the average AOT are for AOT=0.5. The uncertainties are: AOT  $\pm 0.01$ , ratio of the coarse aerosol AOT to the total  $\pm 0.02$ , fraction of photons interacting with the aerosol that are backscattered to space  $\beta$ ,  $\pm 0.01$ , real part of the refractive index  $\pm 0.02$ , single scattering albedo (measure of absorption)  $\omega_0$   $\pm 0.02$ , effective radius of the fine ( $\pm 0.01 \mu\text{m}$ ) and coarse ( $\pm 0.1 \mu\text{m}$ ) modes. In (b) the average values are given for the given boxes. The errors are higher than for AERONET<sup>69</sup>: average AOT  $\pm 0.03$ , coarse AOT / total  $\pm 0.1$  (though not yet fully analyzed),  $R_{\text{eff}} \pm 0.05 \mu\text{m}$  and  $\pm 0.5 \mu\text{m}$  for the fine and coarse modes, respectively. The corresponding forcing at the top and bottom of the atmosphere is derived and reported at the end of the table.**

**a) Analysis of AERONET data<sup>48</sup>**

Aerosol type	Urban / industrial pollution				Biomass Burning		Dust	Pacific ocean
Location	East. US	Euro-pe	S-E Asia	Cen. Amer.	Boreal Forest	Trop. Savanna Africa-S.A.	Sahara – Saudi Arabia	
Months	6 – 9		1-4	1-12		6-11	1-12	1-12
Average AOT <sub>0.55</sub>	0.20		0.20	0.30	0.25 – 0.45	0.25 – 0.5	0.2 – 0.4	0.06
Coarse AOT/total	0.06		0.05	0.10	0.05	0.08	0.75	0.33
$\beta$ at 0.44 $\mu\text{m}$	0.22		0.24			0.25	0.21	0.21
Refractive index	1.40		1.44	1.47	1.47 – 1.50	1.51	1.48 – 1.56	1.36
$\omega_0$ at 0.44 $\mu\text{m}$	0.98	0.95		0.90	0.94	0.88 – 0.91	0.92	0.98
$\omega_0$ at 1.02 $\mu\text{m}$	0.95	0.91		0.83	0.90	0.78 – 0.85	0.98	0.97
$R_{\text{eff}}$ ( $\mu\text{m}$ ) – fine	0.15		0.18	0.14	0.16	0.13	0.12	0.16
$R_{\text{eff}}$ ( $\mu\text{m}$ )–coarse			3.0		3.5	3.5	2.0	2.7

**b) Analysis of MODIS data for Sept. 2000 over ocean**

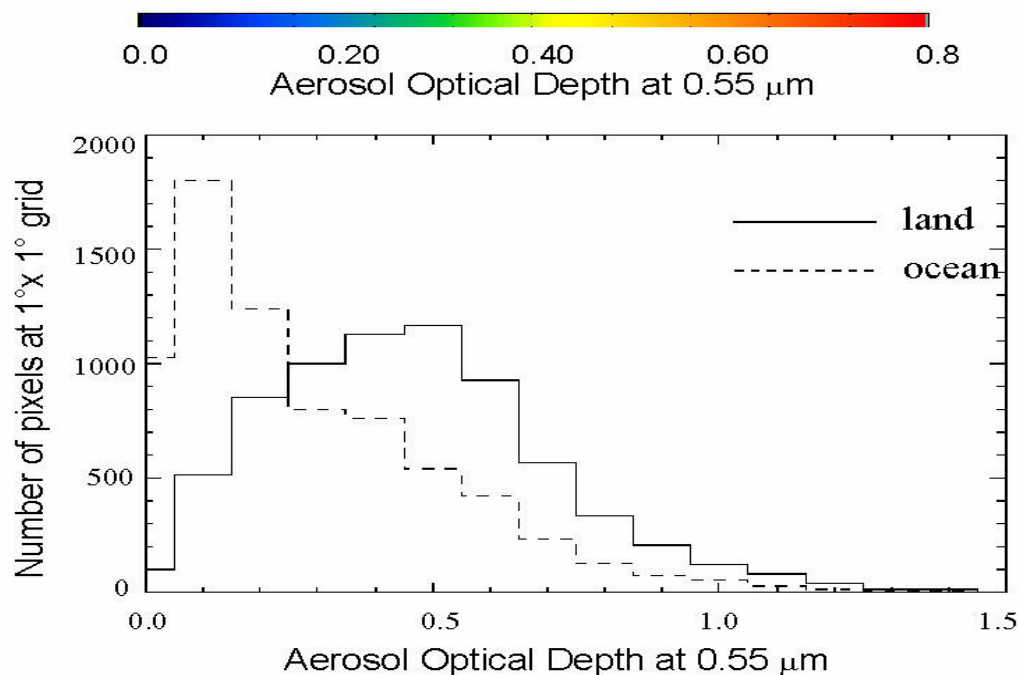
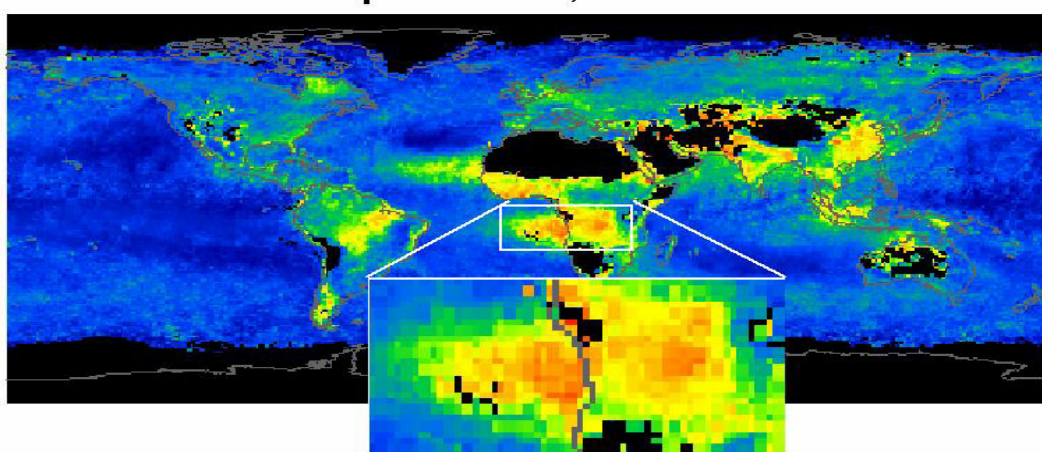
Aerosol type	Urban / industrial pollution		Biomass Burning Savanna		Dust from	
Location	East US	S-E Asia	from South Africa		West Africa	
Area	60-105W 20-45N	70-140E 5-40N	15W-30E, 0-20S		15-50W, 10-25N	
Area (million km <sup>2</sup> )	9.8	22	9		5	
Average AOT <sub>0.55</sub>	0.18	0.24	0.31		0.30	
Coarse AOT / total	0.59	0.56	0.34		0.67	
$R_{\text{eff}}$ ( $\mu\text{m}$ ) - fine	0.15	0.2	0.2		0.2	
$R_{\text{eff}}$ ( $\mu\text{m}$ ) - coarse	1.5	1.6	1.0		1.5	
TOA forcing (Wm <sup>-2</sup> )	-8	-10	-10		-17	
Surface forcing (Wm <sup>-2</sup> )	-10	-23	-30		-23	

## **6. Regional analysis of MODIS aerosol retrievals and NCEP assimilated wind data for various aerosol events**

MODIS aerosol product and NCEP assimilated wind data are analyzed in regions with occurrence of biomass burning source region (Africa) and downwind S. Atlantic Ocean, air

pollution in Italy, and dust transported to Israel. Aerosol optical depth decreases in the downwind of transport path. The comparison of surface wind speed and direction in 1997 between measurements and NCEP model results show good agreement. The NCEP modeled wind field is thus applied to SAFARI 2000 field measurements for the backward trajectory analysis. The lidar and Sun photometer measurements in northern Italy are used to compare with MODIS-derived aerosol optical depth for studying local pollution. Dust aerosols transported to Israel from northern Africa on July 4, 2000 are visible at the surface, which reduced visibility significantly. This shows that the MODIS aerosol retrievals are useful to analyze the aerosol effects at regional scale. The following image shows the aerosol optical depth retrieved by MODIS and histogram shows the decrease of smoke optical depth as transported over ocean from the biomass burning source region.

**September, 2000**



Histogram of aerosol optical depth derived in Southern Africa in September 2000

## **7. Delivery of MODIS PGE04 versions 2.8.0 & 2.8.2 algorithm for consistent-year MODIS data processing**

The MODIS PGE04 versions 2.8.0 and 2.8.2 contain the changes of aerosol retrieval for better screening of snow pixels over land and the addition of new parameters of path radiance and critical reflectance. Snow contamination in aerosol retrieval, as seen, is dramatically reduced in February 2001 (when the new algorithm is in use) as compared to November 2000 - January 2001. The latter can be used to evaluate the empirical relationship in the derivation of surface reflectance in the visible wavelength from 2.1  $\mu\text{m}$  and to derive aerosol single scattering albedo according to the critical reflectance.

## **8. Data analysis of PRIDE MODIS/AERONET measurements**

The Puerto Rican Dust Experiment (PRIDE) observed Saharan mineral dust aerosol above the waters surrounding Puerto Rico, June 26 to July 24, 2000, with the intention of determining the physical, chemical and radiative properties of the dust, the transport processes involved, and the effectiveness of satellite retrievals of dust characteristics in this region. It involved a collaboration of researchers from the Navy (led by Dr. Jeffrey Reid of the U.S. Navy's SPAWAR center, and Dr. Ronald Ferek of the Office of Naval Research), NASA/Goddard, NASA/Ames, the University of Miami, and the University of Puerto Rico.

Observations were made from a twin engine Navajo aircraft carrying the Ames Airborne Tracking Sunphotometer and hyperspectral flux radiometers, an ASD spectrometer, and PCASP and FSSP particle probes. A well-equipped ground site contained a comprehensive array of in situ particle samplers, a transmissionmeter, narrow band and broad band radiometers and a lidar. Additional measurements were made offshore from University of Puerto Rico oceanographic research vessels and included both sunphotometer measurements of the aerosol and bio-optical observations of the sea water and chlorophyll concentration. The experiment was supported continuously by the NRL's dust transport and prediction model. Conditions during the experiment ranged from very clean to moderate dust loading. The heavy dust events noted in Puerto Rico in early June did not re-appear during the deployment. PRIDE, the first attempt of a comprehensive Saharan dust field experiment on the west part of the Atlantic, will provide new knowledge of aerosol characteristics and help validate MODIS aerosol algorithms.

The MODIS-derived aerosol optical depths from direct comparisons with AERONET Sun photometer measurements show high correlation ( $\sim 0.93$ ) with slope of 1.04 at 0.66  $\mu\text{m}$  but with less correlation ( $\sim 0.88$ ) and low-biased (slope  $\sim 0.8$ ) at 0.86  $\mu\text{m}$ . The MODIS-derived underestimated particle sizes indicates the nonsphericity of dust particles. The calibration test of ASD against integrating sphere and gas lamp revealed previously serious problems.

The spectral line error reaches as much as 20 nm, which is far greater than the acceptable range for detecting the spectral variation of various surfaces (e.g., vegetation, snow). After the replacement of a bad detector and replacement of some electronic parts, the calibration reaches a satisfactory level. It is now undergone serious validation with ASD measurements acquired during PRIDE.

Pride data are being used to derive the effect of dust nonsphericity on the dust optical properties and MODIS algorithm.

## **9. Enhancement of the automated daily process of the generation of the MAPSS database from MODIS and AERONET aerosol and water vapor products**

Software of MODIS Aerosol Products Subset Statistics (MAPSS) to subset MODIS and AERONET aerosol products is completed and fully implemented into daily processing stream on Windhoek. It is mainly used to create operational spreadsheet files for validation purpose. A box of 50 km  $\times$  50 km around Sun photometer site is used to calculate statistics of aerosol optical depth, Angstrom coefficient, effective radius, and other related parameters at MODIS over-passing time. For AERONET, the statistics is generated within  $\pm 30$  minutes of MODIS overpasses. The statistics include mean, standard deviation, maximum, minimum, and parameters from linear regression. Because of huge volume of MODIS data, the subset files are extremely useful for data analysis and archival. The enhancement of MAPSS is made to improve the efficiency of data processing, generation, transfer, and web display interface. Aerosol size distribution and single scattering albedo retrieved from Sun photometer sky measurements are planned to be included in the near future.

## **10. Calibration and analysis of Microtops sunphotometer measurements**

The measurement characteristics of five Microtops II Sun photometers have been studied to understand the instrument better and to establish its reliability for use in determining aerosol optical thickness and precipitable column water vapor. The experiment was conducted at the NASA Goddard Space Flight Center (GSFC) facility in Greenbelt, Maryland. Measurements were often taken alongside the automatic tracking AERONET master sunphotometer, which is believed to be reliable, with AOT uncertainty being less than  $\pm 0.01$  at 0.440  $\mu\text{m}$  wavelength and less than  $\pm 0.02$  for shorter wavelengths [Holben, et al. 1998]. Therefore, in this investigation, the GSFC AERONET master sunphotometer has been used as a standard for comparison. Results show that when the Microtops are used in their original state without calibration, their average discrepancies with corresponding AERONET data vary from instrument to instrument. On the average, we found a range of differences with AERONET data of between  $\pm 0.02$  and  $\pm 0.08$  at 0.34  $\mu\text{m}$  among the five Microtops Sun photometers. This discrepancy decreases as the wavelength increases, and

the Microtops/AERONET average difference at 0.87  $\mu\text{m}$  is between  $\pm 0.01$  and  $\pm 0.04$ . However, when properly calibrated against the master AERONET instrument, the Microtops discrepancy with AERONET approaches the uncertainty levels of the AERONET AOT data very closely. In that case, the average differences between the Microtops and AERONET AOT becomes less than  $\pm 0.02$  at 0.34  $\mu\text{m}$  and decrease down to less than  $\pm 0.01$  at 0.87  $\mu\text{m}$ . The use of  $V_0$  calibration from AERONET Sunphotometer is planned to be used for the alternative calibration of Microtops Sun photometer. Both calibration results are included in a paper prepared to submit shortly.

## **11. Coding of transformation of MODIS fire product into climate modeling grid (CMG)**

The coding of generating MODIS fire product in CMG grid is initiated for the need by the climate modeling community. The radiative energy generated from fires may not be correctly characterized by climate model or it is completely absent. The use of MODIS fire channels is able to capture 80% of the radiative energy generated by the biomass burning fires. The code is currently in the initial stage for building of HDF files using the MODIS atmosphere level-3 product as an example.

## **12. Study of sub-pixel snow/ice detection using 0.66 and 2.1 $\mu\text{m}$ channels**

A carefully mapped TM snow scene was analyzed to develop and test the algorithm. The relationship between 0.66 and 2.1  $\mu\text{m}$  is used to identify snow pixels and distinguish them from vegetation. The algorithm is expected to be able to detect sub-pixel snow of several percents. In the process we discovered that MODIS snow algorithm is insensitive to snow contamination when trying to identify snow free pixels. 13-day continuous measurements of snow between different phases are acquired using ASD spectrometer. Sub-pixel snow contamination results in uncertainties in the estimation of surface reflectance and subsequently the retrieval of aerosol optical depth. We further applied the snow algorithm to a MODIS granule over Sierras for the same geographical area as the TM image. The concluded findings are included in a paper submitted to GRL.

## **13. Analysis of Japanese assimilation model results**

Japan assimilation model data sets (from Prof. Terry Nakajima) are used to study the evolution (or transport) and seasonal variation of aerosols at a global scale. Database is generated for total aerosol loading and for each individual aerosol type (dust, sulfate, salt, back carbon) as well as water vapor at twelve locations. The model results show very low cloud fraction of less than 5% in the aerosol transport processes. Despite the unrealistic cloud fraction, the model simulation does resemble well the aerosol distribution.

## **14. Development of aerosol assimilation model**

Aerosol assimilation model is under development via fitting satellite and ground-based aerosol remote sensing data based upon a core of aerosol transport model developed by Dr. P. Ginoux. It is expected that this fitting procedure will improve model prediction by means of correcting aerosol sources being assumed in the model. The reprogramming of the model include the following physical mechanisms

- Aerosol diffusion due to air instability in planetary boundary layer
- Cloud convection
- Dry deposition of aerosol caused by diffusion air motion in air layer near surface
- Aerosol gravitational settling
- Wet removal of aerosol
- Three dimensional aerosol advection

The redesign of the aerosol transport model are finished, including (1) regridding (degradation of the latitudinal, longitudinal, and vertical resolutions) of meteorological fields, (2) reorganization of 3D-advection processes in a form appropriate for inversion, (3) programming of the inversion code for retrieval of the source.

The development of algorithms for the retrieval of aerosol optical parameters from AERONET measurements includes (1) the subroutine changes in order to accommodate the calculation of spectral dependence of spheroidal aerosol particle optical characteristics using kernel function look up table for one wavelength and given a set of aspect-ratios, (2) the calculations of the kernel function look up table for spheroidal particles (which have been finished), and (3) the change of the retrieval code to retrieve aspect-ratio or aspect-ratio distribution of spheroidal aerosol particles.

The continual progresses also include (1) the improvement of computational efficiency (e.g., sparse matrix multiplication), (2) development of numerical procedure of quadratic form minimization, (3) visualization of forward simulation of aerosol transport.

## **15. Participation in ACE-Asia field experiment**

*Selection of ground observation site and setup of instruments:*

Several locations in the vicinity of Dunhuang are considered, including the Dunhuang airport, meteorology station, and Mogao Grotto site. The final site selected is located above Mogao Grottoes at the Sand Control Station of Conservation Institute of the Dunhuang Academy to avoid Dunhuang city pollution (the population of Dunhuang is approximately 160,000 including the city and neighboring villages) and for the safety reason of the instruments. The instruments setup in the field includes 10 ultraviolet-visible-infrared-microwave-shadowband radiometers, micro-pulse lidar, CIMEL Sun photometer, all-sky imager, solar tracker-shadow band radiometer, Nephelometer, Aerodynamic Particle Sizer,

Drum Aerosol Sampler, as well as wind/temperature sensors. All the instruments are operated normally since March 26. The radiometers and Sun photometer were operated a few days earlier than Micropulse lidar, Nephelometer, Aerodynamic Particle Sizer, and Drum Aerosol Sampler. The latter instruments awaited to be housed into a 1.5 m in-length cubic box because of temperature requirement. However, some deficiency of the CIMEL sun-tracking occurred during the beginning of the observation period. A 90-degree rotation of the the sunphotometer collimator-sensor head was performed to produce a better sun-tracking capability. The all-sky imager was suffered by a memory fault of onboard computer and was fixed after the reloading of control programs. The early analysis of micropulse lidar measurements indicated that the temperature fluctuations (10°-35°C) might be a problem for the determination of final vertical extinction profiles.

*Early analysis of aerosol optical depths measured by hand-held Microtops Sun photometer*

A set of aerosol optical depths taken at Beijing on March 12 showed a wavelength dependence of 1.4 with optical depths of 1.6, 1.3, 0.7, and 0.5 at 0.34, 0.44, 0.68, and 0.87  $\mu\text{m}$ . It clearly indicates severe city pollution over Beijing despite dust storms passing through just a few days earlier. A blanket of haze was experienced every day without any noticeable change during the stay at Beijing from March 9 to 12. The measurements of aerosol optical depths taken at Dunhuang site (Mogao Grotto) from March 16 to 27 show consistently nearly zero spectral variation. On March 24, the most clear day, aerosol optical depth is on the magnitude of 0.15 in the morning and 0.3-0.4 in the afternoon hours. The column water vapor measured is on the order of 0.3 cm. Overall during the stay at Dunhuang the water vapor column amounts never exceed 0.5 cm. With very low relative humidity (< 10%), precipitation is nearly impossible. Cirrus clouds are most often seen at Dunhuang. With the presence of thin cirrus clouds, aerosol optical depths can increase significantly. Therefore the contamination by cirrus clouds is a serious matter. Since the separation of signals of cirrus clouds and dust particles is difficult, the current cloud screening process used by AERONET may be insufficient.

## **16. Integration of MODIS data with PICASSO and MISR**

We are working on integration of the inversion process to include MODIS and other sensors that fly or will fly simultaneously, and measure aerosol e.g. MISR, PICASSO lidar and POLDER. The PICASSP work funded also by the PICASSO team includes theoretical component described below and analysis of data from Safari and Shade experiments that just began.

Two wavelength space lidar observations, such as those on PICASSO-SCENA, have valuable information about the vertical distribution of aerosol particles. However the two wavelength backscattering information cannot be uniquely mapped into the aerosol physical properties. Infinite number of physical solutions with different attenuations through the atmosphere can reconstruct the same two wavelength backscattered profile. Spectral radiance measured by MODIS simultaneously with the PICASSO data can help constrain the problem and resolve this ambiguity. Sensitivity study shows that inversion of the integrated MODIS+PICASSO data can derive the vertical profile of the fine and coarse modes mixed

in the same atmospheric column in the presence of calibration errors and electronic noise. – a paper summarizing the work is in progress.

## **17. Papers published/accepted/submitted**

### **MODIS validation**

1. **Remer, L. A., D. Tanré, Y. J. Kaufman, C. Ichoku, S. Mattoo, R. Levy, D. A. Chu, B. N. Holben, J. V. Martins, and R.-R. Li and Z. Ahmad**, Validation of MODIS Aerosol Retrieval Over Ocean, submitted to GRL 2001
2. **Chu, D. A., Y. J. Kaufman, C. Ichoku, L. A. Remer, D. Tanre, and B. N Holben**: Validation of MODIS aerosol optical depth retrieval over land, submitted to GRL, 2001
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## **18. Conference/workshop**

MODIS Science Team Meeting, Greenbelt, Maryland, January 22 - 26, 2001.

DOE Fire Safety Workshop, Augusta, Georgia, April 23 - 27, 2001.

EOS/Terra Cloud Mask Workshop, Madison, Wisconsin, May 8 - 9, 2001.

European Association of Remote Sensing Laboratories (EARSeL) Symposium & Workshop (May 14 - 18, 2001).

PRIDE data analysis workshop, San Diego, California, June 6 - 7, 2001.

EOS Terra Data Product Workshop, George Mason University, Virginia, June 4-11, 2001.

IAMAS meeting 2001 Innsbruck, Remote Sensing of Aerosol and their Radiative Properties from the MODIS Instrument on EOS-Terra Satellite - First Results and Evaluation